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(54) APPARATUS FOR THE EVAPORATION OF A LIQUID AND IT'S SUBSEQUENT CONDENSATION

VORRICHTUNG ZUM VERDAMPFEN EINER FLüSSIGKEIT UND IHRER NACHFOLGENDEN KONDENSATION

APPAREIL POUR L'EVAPORATION D'UN LIQUIDE ET SA CONDENSATION ULTERIURE

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Description

The present invention relates to an apparatus for the evaporation of a liquid and for its subsequent condensation, the apparatus comprising a plurality of flat, bag-like elements of a thin film material, such as plastic film, placed one against the other, the elements serving as heat exchangers between a vaporizing liquid which flows along the exterior surfaces of the elements and a condensing vapor which has been directed to the inside of the elements, and a compressor for increasing the pressure and temperature of the generated vapor before it is directed to the inside of the elements.

An apparatus according to the above definition is described in, for example, FI Lay-Open Print 79948 and in the corresponding International Application Publication WO 90/01977. The primary use of apparatuses of this type has been the production of fresh water from sea water. The tube or plate heat exchangers used in the prior art for the distillation of sea water were susceptible to contamination, and the corrosive nature of sea water caused problems of corrosion in them, necessitating the use of expensive, non-corrodible materials such as titanium and cupro-nickel. By the use of bag-like distillation elements made of plastic film these disadvantages have been eliminated, since plastic film is inexpensive, non-corrodible and, owing to its resilience, less susceptible to contamination. Any contaminant possibly adhering to the membranes can be shaken off by varying the pressure prevailing inside the elements. It has been possible to compensate for the poor thermal conductivity of plastic per se by using in the distillation apparatus a very thin film and a large number of thin elements having a large heat exchange surface.

The distillation apparatus according to said FI Lay-Open Print 79948 comprises, above the plastic membrane elements, a common distribution basin for the water to be evaporated, from which the liquid flows via pipes into the passages between the elements. The vapor generated on the exterior surfaces of the elements is directed to a blower, which blows it, at a higher pressure and temperature, to the inside of the elements through apertures in their sides. The system described has the disadvantage that, by means of it, the vapor to be condensed cannot be spread very evenly inside the elements, and subsequently part of the potential condensing efficiency of the apparatus remains unexploited. Also, in the apparatus disclosed, the spreading out of the liquid to be evaporated over the exterior surfaces of the elements does not occur in the best possible manner. Thus, heat exchange between the liquid vaporizing on the exterior surfaces of the elements and the vapor condensing inside the elements remains incomplete.

The object of the present invention is to provide an apparatus in which heat exchange is enhanced especially by causing the vapor to be condensed to spread more evenly than in prior art inside the elements. The invention is characterized in that the inside of each bag-like element is divided into parallel vapor ducts extending vertically from one end of the element to the other, and that the feeding of vapor into the said ducts is arranged to take place from apertures located at the upper edge of the element and leading to the inside of the element.

By the system according to the invention, vapor can be directed to the inside of the elements and be caused to flow in them from the top downwards as an even flow distributed over the entire width of the elements. The condensing efficiency of the elements can thus be exploited maximally.

The vapor ducts to be formed in the bag-like elements may, according to the invention, be produced by seaming the opposite membranes of each element to one another along vertical seaming lines. By leaving in the seaming lines breaks at which the parallel ducts communicate with each other, an evening-out of the flow is further promoted by enabling the vapor and the liquid condensing from it to pass to some extent from one duct to another.

The feeding in of the vapor to be condensed can advantageously be arranged to take place via a honeycomb-structured end strip having substantially the width of the element and being located at the upper edge of each element. Such an end strip, which contains a plurality of parallel feeding ducts separated from each other by partition walls enables vapor to be fed evenly to the inside of the element and serves at the same time as a support part which facilitates the handling and installation of the element.

According to one preferred embodiment of the invention, the honeycomb-structured end strip preferably comprises a honeycomb board in which the space between two opposite walls is divided by transverse, mutually parallel partition walls into parallel ducts of equal width. Such a plastic honeycomb board is a commonly available commercial product, which has so far been used in various support and insulation structures in which the ducts have constituted voids providing insulation and making the structure lighter. In the present invention, however, they serve as a simple and inexpensively produced flow-channel system which feeds the liquid evenly to the inside of the element over the entire width of the end of the element, and is not susceptible to the corrosive action of the liquids being distilled.

The vapor-feeding ducts contained in the end strip of the element are preferably substantially vertical, the vapor-feeding direction corresponding to the principal flow direction of the vapor in the vapor ducts formed inside the element. The orientation of the feeding ducts can be achieved simply by cutting the end strip out of a larger honeycomb board made up of two opposite walls and of mutually parallel partition walls between them, the cut being at a suitable angle to the said partition walls.

One preferred embodiment of the invention is characterized in that the end strip of the element comprises a honeycomb in which the space between two opposite walls is divided into parallel ducts feeding the vapor to be condensed to the inside of the element, and in which at least one of the adjacent spaces between two opposite

walls is divided into parallel ducts feeding the liquid to be evaporated onto the exterior surface of the element. By this system there is accomplished simultaneously both a maximally even distribution of the vapor to be condensed inside the element and a maximally even distribution of the liquid to be evaporated over the exterior surface of the element, thus achieving the best possible heat exchange between the condensing vapor and the vaporizing liquid.

The most preferred embodiment of the system referred to above is that the honeycomb constituting the end strip has, on both sides of the vapor-feeding ducts leading to the inside of the element, feeding ducts which distribute the liquid to be evaporated onto both exterior surfaces of the element.

In addition to the honeycomb-structured end strips at the upper ends of the elements, the apparatus according to the invention may also have at the lower end of each element a honeycomb-structured end strip having substantially the width of the element, the end strip containing a plurality of outlet ducts for the liquid condensed inside the element. For the end strip of the lower end of the element it is also possible to use commercially available plastic honeycomb boards in which the space between two opposite walls is divided by transverse, mutually parallel partition walls into parallel ducts of equal width.

The end strip at the lower end of the element is preferably made up of a honeycomb in the middle of which the space between two walls is divided into parallel outlet ducts for the liquid condensed inside the element, and in which, on one side, preferably on both sides of the said space, the space between two opposite walls is divided into outlet ducts for the liquid which has remained unvaporized on the exterior surface of the element. The outlet ducts for the condensed liquid, which constitutes the distillate obtained, may be directed to a common collection space at the side of the elements, whereas the outlet ducts for the unvaporized liquid are preferably vertical, in which case they will discharge the liquid to the bottom of the apparatus by the shortest route.

The invention is described below in greater detail with the help of examples, with reference to the accompanying drawings, in which

Figure 1 depicts a schematic cross section of one apparatus according to the invention,
Figure 2 depicts a side view of one bag-like element belonging to the apparatus according to Figure 1,
Figure 3 depicts a section through III-III in Figure 2,
Figure 4 depicts a section through IV-IV in Figure 2,
Figure 5 depicts a section through V-V in Figure 2, and
Figure 6 depicts a section through VI-VI in Figure 2.

The apparatus according to Figure 1 comprises a frame 2 in the space defined by which there is a plurality of flat, bag-like elements 3 made of thin plastic film, placed one against the other. At the upper end of each element 3 there is a honeycomb-structured plastic end strip 4, one end of which communicates with a distribution basin 5 containing the liquid to be evaporated, common to all the elements, and its upper side communicates with the feeding chamber 6 containing the vapor to be condensed, also common to all the elements. At the lower end of each element 3 there is a honeycomb-structured plastic end strip 7, one end of which communicates with a collection vessel 8 for the distillate condensed from the vapor, and under which the bottom of the frame has been formed into a collection basin 9 for the liquid which has remained unvaporized in the apparatus. Between the said end strips 4, 7 each bag-like element 3 is made up of two opposite plastic membranes 11 which have been welded to each other along vertical zigzagging seaming lines 10. The seaming lines 10 delimit, inside the element 3, vertical ducts 12 extending from one end of the element to the other, in which ducts the vapor condenses into liquid. The seaming lines 10 are not continuous but include breaks at which vapor or liquid may to a limited degree pass from one duct 12 to another. The vapor generated from the liquid fed onto the exterior surfaces of the elements 3 flows from the spaces between the elements, in accordance with arrows 13 in Figure 1, into a suction chamber 14 surrounding the elements, from which chamber a blower 15 serving as the compressor blows the vapor, at a higher pressure and temperature, via a pipe 16 into the vapor-feeding chamber 6 at the upper end of the apparatus.

The inlet pipe for the liquid to be evaporated, which leads to the distribution basin 5, is indicated by reference numeral 17 in Figure 1. The outlet pipe for the distillate obtained is indicated by numeral 18, and the outlet pipe for the unvaporized liquid by numeral 19. The discharging distillate and the liquid which has remained unvaporized are used in heat exchangers 20 for preheating the liquid to be distilled.

The structure and operation of each individual element 3 of the distillation apparatus 1 can be seen in greater detail in Figures 2-6. The function of the end strip 4 at the upper end of the element is to distribute the vapor to be condensed, blown into the feeding chamber 6, as evenly as possible into the vertical ducts 12 inside the element and to distribute the liquid to be evaporated, which is in the distribution basin 5, as evenly as possible onto the opposite exterior surfaces 21 of the element. The function of the end strip 7 at the lower end of the element, for its part, is to collect the liquid condensed in the ducts 12 inside he element and to direct it as the obtained distillate to the collection vessel 8 and to allow the liquid which has remained unvaporized on the element surfaces 21 to flow into the collection basin 9 at the bottom of the apparatus.

The upper end strip 4 of the element comprises, in accordance with Figures 2-4, a honeycomb produced from three opposite, substantially rectangular plastic honeycomb boards 22. In each of these boards 22 the space between two opposite walls 23 is divided by transverse, mutually parallel partition walls 24 into parallel

ducts of mutually equal width. The ducts in the middle honeycomb board of the strip form the ducts 25 leading to the inside of the element, for the vapor to be condensed, and the ducts in the honeycomb boards on their both sides constitute the feeding ducts 26, leading to the opposite exterior surfaces 21 of the element, for the liquid to be evaporated. As can be seen in Figure 2, the feeding ducts 25 for the vapor to be condensed are vertical, in which case they direct the vapor vertically into the ducts 12 produced inside the element by means of seams, whereas the feeding ducts 26 for the liquid to be evaporated run obliquely from the end 27 of the strip 4 to the side 28 of the strip, from which the liquid discharges onto the element surfaces 21. Both the vapor directed to the inside of the element 3 and the liquid directed onto its surfaces 21 can thus be distributed evenly over the entire width of the element, whereby the best possible heat exchange is accomplished between the vapor phase and the liquid phase.

The honeycomb-structured end strip 7 at the lower end of each element is structurally similar to the end strip 4 of the upper end of the element. There is, however, the difference that, of the three opposite honeycomb boards 29 of the strip 7, the middle one contains ducts 31 which lead obliquely towards the end 30 of the strip, communicate with the vertical ducts 12 seamed inside the element, and serve as outlet ducts for the liquid condensed inside the element, whereas in the honeycomb boards on both sides of these the ducts 32 are vertical and serve as outlet ducts for the liquid remaining unvaporized.

For an expert in the art it is evident that the various embodiments of the invention are not restricted to the above example but may vary within the scope of the accompanying claims. It is, for example, advantageous if the vertical zigzagging ducts 12 in adjacent elements run cross-wise in relation to each other, in which case the elements will not adhere to each other and the downward-flowing liquid to be evaporated will remain more evenly distributed on the exterior surfaces 21 of the elements. If the elements 3 are identical, this requires the reversal of every second element, in which case the liquid-distribution basin 5 and the distillate-collection vessel 8 in the apparatus must be connected to both ends of both the upper end strips 4 and the lower end strips 7.

The uses of the apparatus according to the invention may also vary. In addition to the distillation of sea water, the apparatus is also applicable, for example, to the concentration of various solutions and suspensions, such as the waste waters from bleaching in pulp mills.

Claims

1. Apparatus (1) for the evaporation of a liquid and for its subsequent condensation, the apparatus comprising a plurality of flat, bag-like elements formed from a thin film material, such as plastic film, and placed against one another, the elements serving as heat exchangers between a vaporizing liquid flowing along the exterior surfaces (21) of the elements and a condensing vapor directed to the inside of the elements, and a compressor (15) for increasing the pressure and temperature of the generated vapor before it is directed to the inside of the elements, **characterized** in that the inside of each bag-like element (3) is divided into parallel vapor ducts (12) extending vertically from one end of the element to the other, and that the feeding in of vapor into the said ducts has been arranged to take place from apertures (25) located at the upper edge (4) of the element and leading to the inside of the element.

2. Apparatus according to Claim 1, **characterized** in that the vapor ducts (12) are produced by seaming the opposite membranes (11) of a bag-like element (3) to each other along vertical seaming lines (10).

3. Apparatus according to Claim 2, **characterized** in that the seaming lines (10) have breaks at which the parallel vapor ducts (12) communicate with each other.

4. Apparatus according to any of the above claims, **characterized** in that at the upper edge of each element (3) there is a honeycomb-structured end strip (4) having substantially the width of the element, the strip containing parallel feeding ducts (25) leading to the inside of the element and being separated from each other by partition walls.

5. Apparatus according to Claim 4, **characterized** in that the said ducts (25) leading to the inside of the element (3) are substantially vertical.

6. Apparatus according to Claim 4 or 5, **characterized** in that the end strip (4) preferably comprises a plastic honeycomb board (22) in which the space between two opposite walls is divided by transverse, mutually parallel partition walls (24) into parallel ducts (25) of equal width.

7. Apparatus according to any of Claims 4-6, **characterized** in that the end strip (4) comprises a honeycomb in which the space between two opposite walls is divided into parallel ducts (25) feeding the vapor to be condensed to the inside of the element (3), and in which at least one adjacent space between two opposite walls is divided into parallel ducts (26) feeding the liquid to be evaporated onto the exterior surface (21) of the element.

8. Apparatus according to any of the above claims, **characterized** in that at the lower end of each element (3) there is a honeycomb-structured end strip (7) having substantially the width of the element, the strip containing a plurality of outlet ducts (31) for the liquid condensed inside the element.

9. Apparatus according to Claim 8, **characterized** in that the end strip (7) at the lower end of the element (3) comprises a plastic honeycomb board (29) in which the space between two opposite walls is divided by transverse, mutually parallel partition walls into parallel ducts (31) of equal width.

10. Apparatus according to Claim 8 or 9, **characterized** in that the end strip (7) at the lower end of the element (3) comprises a honeycomb in which the space between two opposite walls is divided into parallel outlet ducts (31) for the liquid condensed inside the element and in which at least one adjacent space between two opposite walls is divided into outlet ducts (32) for the liquid which has remained unvaporized on the exterior surface (21) of the element.

Patentansprüche

1. Vorrichtung (1) zur Verdampfung einer Flüssigkeit und deren darauffolgende Kondensation, welche eine Vielzahl von flachen, taschenartigen Elementen, die aus einem dünnen Folienmaterial, wie Plastikfolie, geformt und aneinandergesetzt sind, wobei die Elemente als Wärmetauscher zwischen einer verdampfenden, entlang den Elementaußenflachen (21) fließenden Flüssigkeit und kondensierendem, in das Elementinnere geleiteten Dampf dienen, und einen Kompressor (15) zur Erhöhung des Druckes und der Temperatur des erzeugten Dampfes, bevor dieser in das Elementinnere geleitet wird, umfaßt, dadurch gekennzeichnet, daß das Innere eines jeden taschenartigen Elementes (3) in parallele, sich vertikal von einem zum anderen Ende des Elementes erstreckende Dampfleitungen (12) geteilt ist, und daß die Zuführung von Dampf in die Leitungen derart angeordnet ist, daß sie ausgehend von den Öffnungen (25), die sich am oberen Ende (4) des Elementes befinden und in das Elementinnere führen, stattfindet.

2. Einrichtung nach Anspruch 1, dadurch gekennzeichnet, daß Dampfleitungen (12) hergestellt sind, indem die gegenüberliegenden Membrane (11) eines taschenartigen Elementes (3) entlang vertikaler Nahtlinien (10) aneinander gesäumt sind.

3. Einrichtung nach Anspruch 2, dadurch gekennzeichnet, daß die Nahtlinien (10) Unterbrechungen aufweisen, an welchen die parallelen Dampfleitungen (12) miteinander kommunizieren.

4. Einrichtung nach einem der vorhergehenden Ansprüche, dadurch gekennzeichnet, daß sich am oberen Rand eines jeden Elementes (3) ein wabenförmiger Endstreifen (4) befindet, der im wesentlichen die Breite eines Elementes aufweist, wobei der Streifen parallele Zuführleitungen (25) enthält, welche in das Innere des Elementes führen und voneinander durch Trennwände getrennt sind.

5. Einrichtung nach Anspruch 4, dadurch gekennzeichnet, daß die Leitungen (25), welche in das Innere des Elementes (3) führen, im wesentlichen vertikal sind.

6. Einrichtung nach Anspruch 4 oder 5, dadurch gekennzeichnet, daß der Endstreifen (4) vorzugsweise eine Wabenplatte aus Plastik (22) umfaßt, in welcher der Raum zwischen zwei gegenüberliegenden Wänden durch querlaufende zueinander parallele Trennwände (24) in parallele Leitungen (25) von gleicher Breite unterteilt ist.

7. Einrichtung nach einem der Ansprüche 4-6, dadurch gekennzeichnet, daß der Endstreifen (4) eine Wabe umfaßt, in welcher der Raum zwischen zwei gegenüberliegenden Wänden in parallele Leitungen (25), welche den zu kondensierenden Dampf in das Innere des Elementes (3) leiten, unterteilt ist, und in welchem wenigstens ein benachbarter Raum zwischen zwei gegenüberliegenden Wänden in parallele Leitungen (26) unterteilt ist, welche die zu verdampfende Flüssigkeit auf die Außenfläche (21) des Elementes leiten.

8. Einrichtung nach einem der vorhergehenden Ansprüche, dadurch gekennzeichnet, daß sich am unteren Ende eines jeden Elementes (3) ein wabenförmiger Endstreifen (7) befindet, der im wesentlichen die Breite des Elementes aufweist und eine Vielzahl von Auslaßleitungen (31) für die im Inneren des Elementes kondensierte Flüssigkeit enthält.

9. Einrichtung nach Anspruch 8, dadurch gekennzeichnet, daß der Endstreifen (7) am unteren Ende des Elementes (3) eine Wabenplatte (29) aus Plastik umfaßt, in welcher der Raum zwischen zwei gegenüberliegenden Wänden durch querlaufende zueinander parallele Trennwände in parallele Leitungen (31) gleicher Breite unterteilt ist.

10. Einrichtung nach Anspruch 8 oder 9, dadurch gekennzeichnet, daß der Endstreifen (7) am unteren Ende des Elementes (3) eine Wabe umfaßt, in welcher der Raum zwischen zwei gegenüberliegenden Wänden in parallele Auslaßleitungen (31) für die im Inneren des Elementes kondensierte Flüssigkeit unterteilt ist und in welcher wenigstens ein benachbarter Raum zwischen zwei gegenüberliegenden Wänden in Auslaßleitungen (32) für die auf der Außenfläche (21) des Elementes unverdampft gebliebene Flüssigkeit unterteilt ist.

Revendications

1. Un appareil (1) pour l'évaporation d'un liquide et sa condensation ultérieure, l'appareil comprenant plusieurs éléments plats en forme de sac composés d'une matière de structure fine telle qu'une feuille en matière plastique, lesdits éléments étant disposés les uns contre les autres et servant d'échangeurs de chaleur entre un liquide de vaporisation qui s'écoule le long des surfaces extérieures (21) des éléments et une vapeur de condensation dirigée vers l'intérieur de ces éléments, de même qu'il comprend un compresseur (15) destiné à augmenter la pression et la température de la vapeur générée avant son envoi vers l'intérieur des éléments, caractérisé en ce que l'intérieur de chaque élément (3) en forme de sac est divisé en canaux parallèles (12) de circulation de vapeur s'étendit verticalement depuis une extrémité de l'élément à l'autre extrémité et en ce que l'alimentation de la vapeur à l'intérieur desdits canaux est prévue pour avoir lieu à partir des ouvertures (25) situées sur la face supérieure (4) de l'élément et menant vers l'intérieur de l'élément.

2. Un appareil selon la revendication 1, caractérisé en ce que les canaux (12) de circulation de vapeur sont fabriqués par l'assemblage des membranes opposées (11) de chaque élément (3) en forme de sac l'un avec l'autre le long de lignes de soudure verticales (10).

3. Appareil selon la revendication 2, caractérisé en ce que les lignes de soudure (10) présentent des interruptions par lesquelles les canaux parallèles (12) de circulation de vapeur communiquent les uns avec les autres.

4. Appareil selon l'une ou l'autre des revendications précédentes, caractérisé en ce que sur la face supérieure de chaque élément (3) est placée une bande d'extrémité (4) de structure alvéolaire présentant substantiellement la largeur de l'élément, ladite bande contenant des canaux d'alimentation (25) parallèles menant vers l'intérieur de l'élément et étant séparés l'un de l'autre par des cloisons.

5. Appareil selon la revendication 4, caractérisé en ce que lesdits canaux (25) menant vers l'intérieur de l'élément (3) sont substantiellement verticaux.

6. Appareil selon l'une ou l'autre des revendications 4 et 5, caractérisé en ce que la bande d'extrémité (4) comprend de préférence une plaque alvéolaire en plastique (22) dans laquelle l'espace séparant deux parois opposées est divisé par des cloisons (24) parallèles transversales en canaux (25) parallèles de largeur égale.

7. Appareil selon l'une ou l'autre des revendications 4 à 6, caractérisé en ce que la bande d'extrémité (4) comprend une plaque alvéolaire dans laquelle l'espace séparant deux parois opposées est divisé en canaux parallèles (25), lesquels alimentent la vapeur devant être condensée vers l'intérieur de l'élément (3) et dans laquelle au moins un espace adjacent séparant deux parois opposées est divisé en canaux parallèles (26) alimentant le liquide devant être évaporé sur la surface extérieure (21) de l'élément.

8. Appareil selon l'une ou l'autre des revendications précédentes, caractérisée en ce que à l'extrémité inférieure de chaque élément (3) est prévue une bande d'extrémité (7) de structure alvéolaire présentant substantiellement la largeur de l'élément, la bande d'extrémité contenant plusieurs canaux de sortie (31) pour le liquide condensé à l'intérieur de l'élément.

9. Appareil selon la revendication 8, caractérisé en ce que la bande d'extrémité (7) à l'extrémité inférieure de l'élément (3) comprend une plaque alvéolaire (29) en plastique dans laquelle l'espace séparant deux parois opposées est divisé par des cloisons parallèles transversales en canaux parallèles (31) de largeur égale.

10. Appareil selon l'une ou l'autre des revendications 8 et 9, caractérisé en ce que la bande d'extrémité (7) à l'extrémité inférieure de l'élément (3) comprend une plaque alvéolaire dans laquelle l'espace séparant deux parois opposées est divisé en canaux parallèles de sortie (31) pour le liquide condensé à l'intérieur de l'élément et dans laquelle au moins un espace adjacent séparant deux parois opposées est divisé en canaux de sortie (32) pour le liquide non-vaporisé sur la surface extérieure (21) de l'élément.

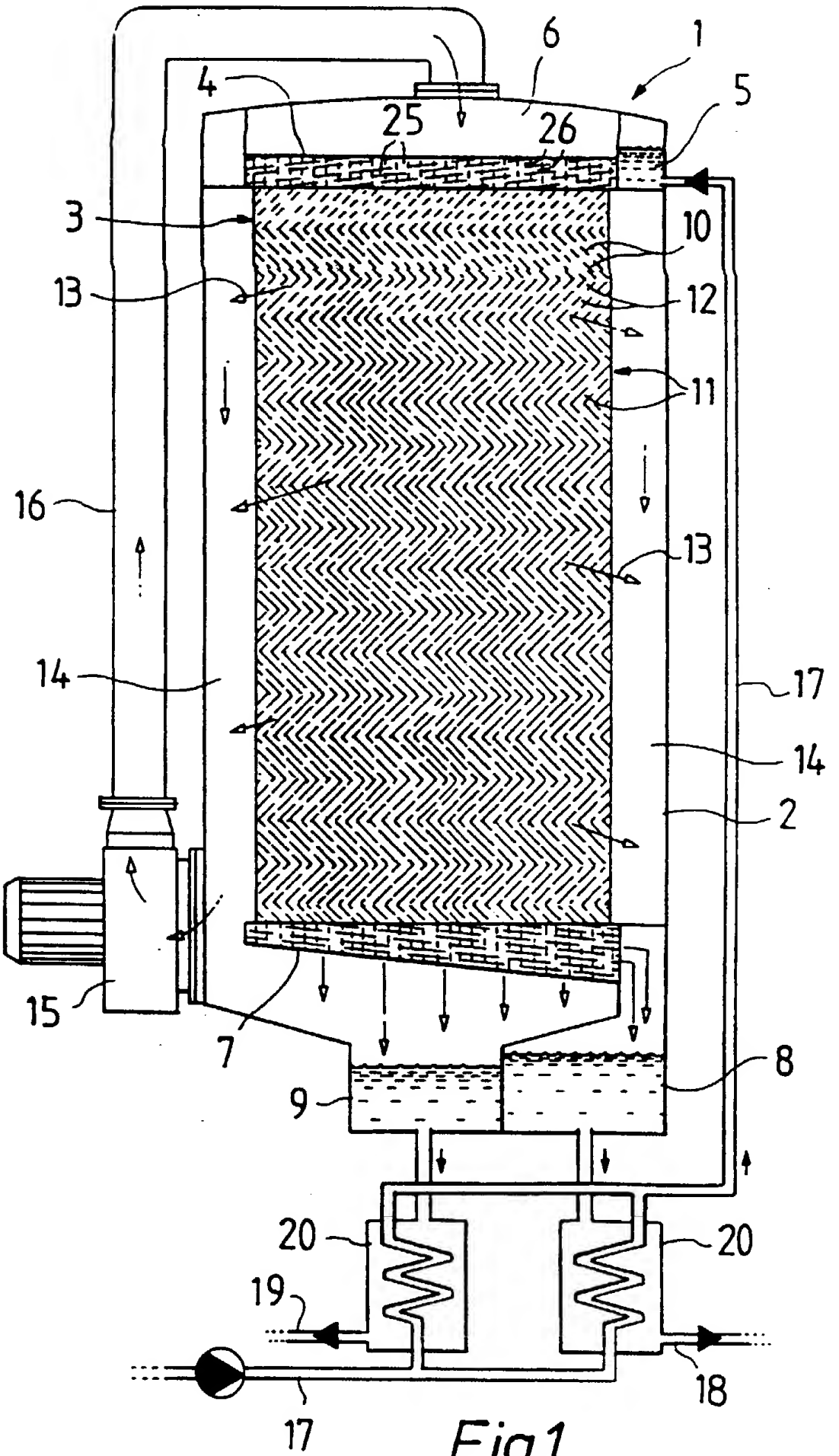

Fig.1

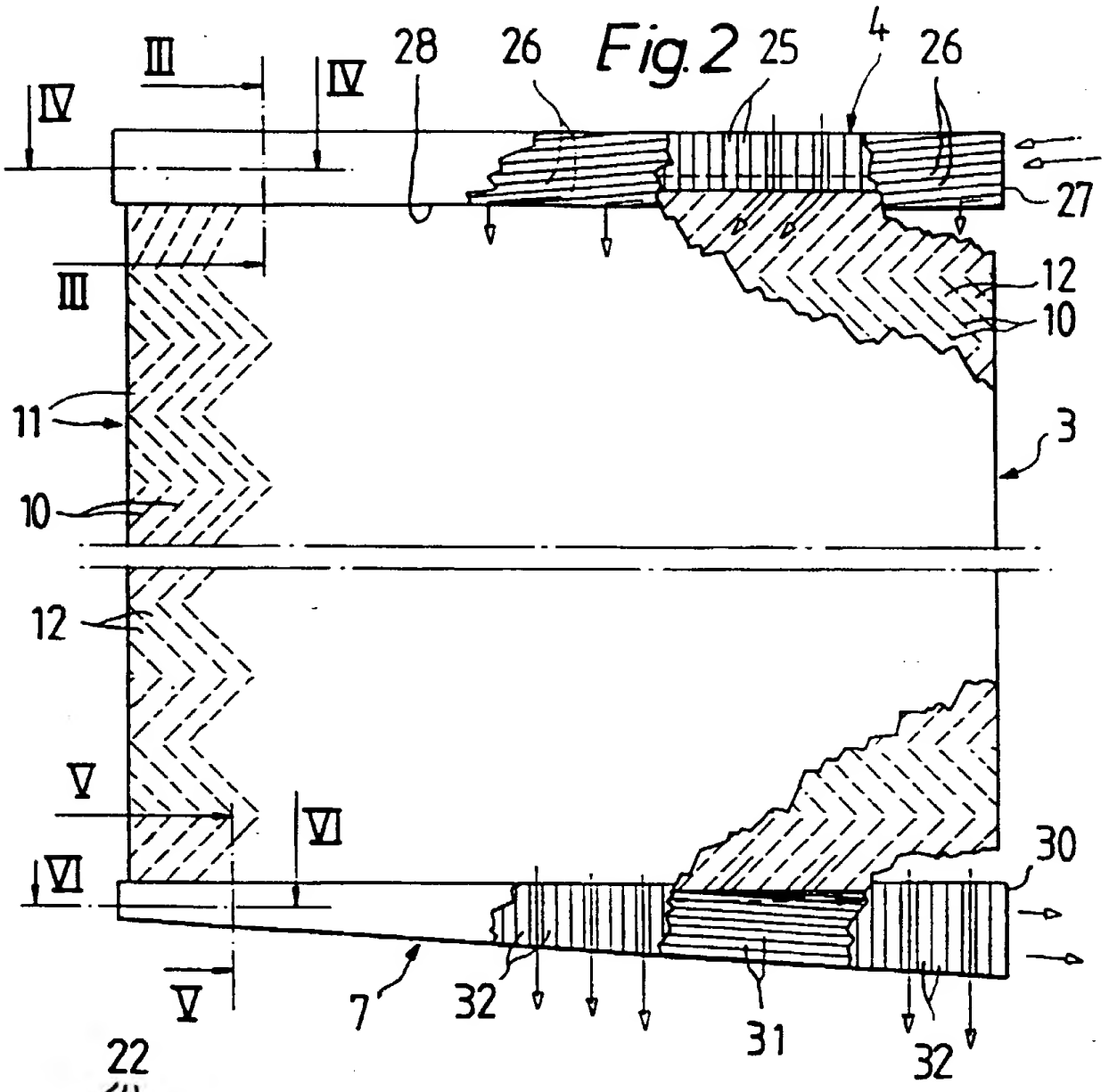

Fig.2

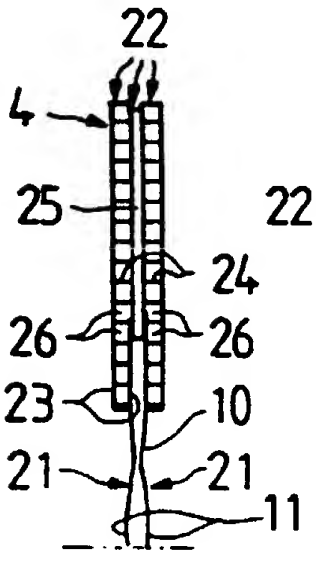

Fig.3

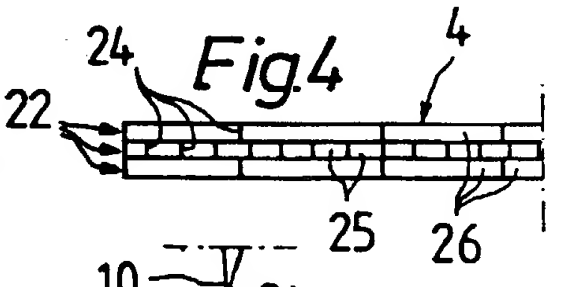

Fig.4

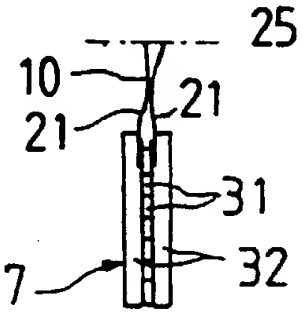

Fig.5

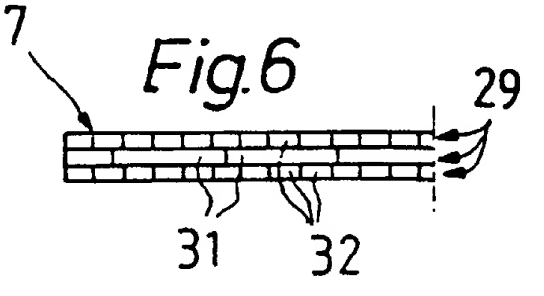

Fig.6